Design and Optimization of SNCR/SCR Hybrid on a Group 1 Boiler in the Ozone Transport Region

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A full scale SNCR/SCR Hybrid system, NOxOUT CASCADE®, has been designed and installed at the GPU GENCO Seward Station, Unit #15 boiler. The Seward Station hybrid system is a combination of a redesigned existing SNCR with a new downstream SCR. Significant improvements in chemical utilization and overall NOx reduction have been seen in preliminary testing of the SNCR when ammonia slip was permitted to increase above normal operational limits.

The integrated system was designed using advanced computational fluid dynamics and cold flow modeling techniques. The units two air pre-heater ducts were retrofit with different types of catalyst, honeycomb in one and plate in the other. Reactor and duct internals were designed to compensate for an existing ash loading imbalance, temperature and velocity variation, and a difference in the SCR pressure drop between the two ducts.

Hybrid SNCR/SCR is a combination of a redesigned SNCR and downstream SCR, hybridized to provide improvements in chemical utilization and overall NOx reduction. The two NOx reduction technologies each provide process strengths which make the hybrid combination more flexible and effective than the sum of its parts.

Selective Non-Catalytic Reduction (SNCR) is typically applied in the furnace, where relatively high temperatures serve to initiate the breakdown of urea to form the transient species which lead to effective NOx reduction. The technology is limited to temperatures high enough to insure very low ammonia breakthrough. At very high furnace temperatures, however, performance can be lessened by competing reactions which either consume effective chemical or lead to NOx formation. Modified SNCR takes advantage of a downstream “ammonia sink” by injecting chemical in cooler regions where NOx reduction and chemical utilization improve dramatically.

Selective Catalytic Reduction (SCR) is typically performed in much cooler flue gas passes where the oxidation potential of nitrogen species is minimized. The catalytic surface provides sites which permit the ammonia and NOx to react at nearly perfect utilization. The extent of NOx reduction is limited by the local ammonia to NOx ratio, the flue gas temperature, and the size of the catalyst reactor. The catalyst size is limited by the available space, an increase in pressure drop, the oxidation of SO_2 to SO_3, and the cost of the precious metal components.

Hybrid SNCR/SCR NOx utilizes lower temperature SNCR injection to provide substantially improved NOx reduction performance while generating somewhat higher ammonia slip. The ammonia slip feeds a small SCR reactor which removes the slip and reduces NOx while limiting the costs associated with a larger catalyst. For example, a CASCADE system which achieves 65% overall NOx reduction (50% reduction with SNCR and an additional 30% SCR reduction) requires less than one third the catalyst required for 65% SCR reduction. The smaller catalyst converts proportionally less SO_2 to SO_3 and decreases the pressure drop by the same fraction.

The Hybrid process was tested at Public Service Electric and Gas, Mercer Station. The unit, which had an existing SNCR system, was partially retrofitted with an expanded duct catalyst as part of a study of SCR, combined SNCR-SCR, and Hybrid SNCR/SCR. In this preliminary work it was shown that deeper than design reductions in NOx were possible through modification of the SNCR system with less than design chemical (urea) flow rates. This was achieved by decreasing the effective chemical release temperature in the furnace.

The by-product of this temperature shift, excessive ammonia slip, was utilized in the SCR reactor where further NOx reduction was achieved and ammonia slip levels were reduced to within acceptable limits. Although the SCR reactor was large enough to provide greater than 85% NOx reduction on its own, it was shown that ammonia and NOx distributions to the catalyst were sufficiently uniform to allow for a substantial reduction in catalyst volume without adversely affecting the process.

A Hybrid SNCR/SCR system has been designed, constructed, and installed for GPU GENCO, at Seward Station, Boiler #15. This unit is a Combustion Engineering, coal burning, tangentially fired boiler rated at 148 MW gross electrical output. Current minimum load is 90 MWg, but it may become necessary to operate at loads as low as 74 MWg (50% MCR).

A commercial NOxOUT® SNCR had been previously installed at Seward Station. The system provided the required NOx reduction from a 1990 baseline of approximately 0.78 lb/10^6 Btu to 0.45 lb/10^6 Btu with less than 5 ppmv slip. High concentrations of SO_2, and therefore SO_3, as well as cool air pre-heater exit temperatures combined to make this installation particularly sensitive to ammonium salt formation. It is currently being operated at reduced efficiency (approximately 0.5 lb/10^6 Btu) to produce less than 2 ppmv ammonia slip. As much as 75% of the chemical is injected into the furnace where utilization is relatively low. The remaining chemical is injected behind the super heater tubes, above the arch, through multi-nozzle lances which provide excellent chemical distribution and extremely high chemical utilization.

The Hybrid system at Seward Station is expected to provide overall NOx reduction of at least 55%, to 0.35 lb/10^6 Btu, from the 1990 baseline at less than 2 ppmv ammonia slip. The primary injection zone will be significantly cooler and the chemical utilization is expected to increase dramatically from the current SNCR system. Overall chemical flow is not expected to increase.

System testing and optimization are currently being completed and results will be presented. SNCR performance was initially designed to achieve 42% reduction with an NSR of 1.3 and a resulting chemical utilization of 33%. Based on preliminary testing, performance is expected to increase to at least 55% reduction with an NSR of 1.2, a decrease in chemical flow, and a resulting overall chemical utilization in excess of 45%.

Pending the results of complete testing, which will verify the performance estimates of the catalyst vendors, it will be possible to achieve 65% overall NOx reduction with the addition of catalyst to the reactor vessel. This new design may also require additional convective pass chemical injection, but the total chemical flow rate is not expected to increase significantly.

The use of hybrid SNCR/SCR systems permits ìtailoringî NOx reduction and life-cycle cost to the potentially complex future requirements of NOx reduction for ozone mitigation. The total life cycle cost of the modified SNCR/SCR NOx reduction process is a function of chemical utilization and catalyst size and capital requirement. Very high NOx reductions, of perhaps 90%, require a substantial catalyst volume. This system cannot be placed in existing duct dimensions and will always require, at the very least, major modifications. A modified SNCR/SCR system, providing between 50-60% precatalytic reduction, would require between 75-80% further NOx reduction to achieve 90% overall. This would still demand 88% of the original catalyst volume. Similarly, for an overall NOx reduction of 75%, a stand-alone SCR system requires approximately 88% of the original high reduction catalytic volume.

A modified SNCR/SCR process would conceptually be effective for approximately 75% overall NOx reduction. Precatalytic SNCR reduction of 50-60% requires only 38-50% SCR reduction, and no more than half of the original catalyst volume as designed for 90% reduction. This is also only 57% of the catalyst volume required for stand-alone SCR targeted at 75% overall reduction. An ìin-ductî catalyst may be used on a site-specific basis to fulfill this half-sized volume requirement.

The field demonstration of that hybrid SNCR/SCR system verified that on a coal-fired unit, the SNCR-related cost performance can be improved substantially. This installation of in-duct (existing duct) catalyst on a pulverized coal-fired unit provides a basis of broad applicability to the various types of boilers within this population.

Conclusions

1. A Hybrid SNCR/SCR system has been designed and installed for a full scale retrofit of a tangentially fired coal boiler in the Ozone Transport Region.

2. Two types of catalyst have been incorporated into the design to provide insight into the achievable performance of various small in-duct reactors.

3. Extensive CFD and cold flow modeling has been completed to provide the required temperature, velocity, and ash distribution profiles required by the catalyst vendors.

4. Chemical utilization and NOx reduction are expected to increase dramatically as compared to stand-alone SNCR.

5. Hybrid SNCR/SCR is capable of addressing the control requirements for many coal-fired boilers in the Ozone Transport Region with up to 75% NOx reduction.

6. Test results will be presented at this conference.